Shelfbreak Acoustics: The ASIAEX Volume Interaction Experiment

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LONG TERM GOALS

The long term goal of our work in the ASIAEX program is to understand the nature of low frequency (50-600 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present. We are also greatly interested in the effects of geological variability, which is as important to acoustics as ocean variability in shallow water regions.

OBJECTIVES

In the ASIAEX experiment, there were a large number of specific acoustics objectives that were pursued - we will not list them all here. Some of these objectives are being pursued by WHOI and some by other ASIAEX P.I.'s. Over the last year, we have specifically focused on the issues of: 1) horizontal array coherence in shallow water, 2) the travel time and intensity fluctuations of the acoustic field in the 50-600 Hz band, and 3) the ambient noise field in the 50-1400 Hz band. These efforts both reinforced and extended the goals of the two predecessor experiments to ASIAEX, the 1995 SWARM internal wave experiment and the 1996-97 PRIMER shelfbreak front experiment. We also are pursuing studies of the physical oceanography and geology of the South China Sea (SCS) volume experiment region, in an interdisciplinary approach together with other ASIAEX investigators.

APPROACH

Similar to the SWARM and PRIMER experiments, the ASIAEX SCS effort combined high-resolution physical oceanographic and geologic measurements with precise measurements of the acoustic field (see Figure 1.) Acoustically, the heart of our experiment was a combined vertical/horizontal aperture array, which listened to both moored and towed sources with frequencies from 50 Hz to 600 Hz. The moored sources enabled us to examine acoustic propagation time series both for a cross slope and an along slope geometry. The towed sources allowed us to study propagation loss versus range, a simple study that had been intended in previous experiments, but had never been accomplished due to time constraints. The receiver array was also able to support ambient noise studies in the 50-1400 Hz band. The oceanographic support for the acoustics was quite extensive, consisting of twenty-nine separate oceanographic moorings, a Sea Soar hydrography survey, a high frequency acoustic backscatter survey, satellite imagery (SAR and AVHRR), and numerous CTD casts. The geological support was also good, consisting of two high-resolution chirp sonar surveys along the stationary propagation

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14. ABSTRACT
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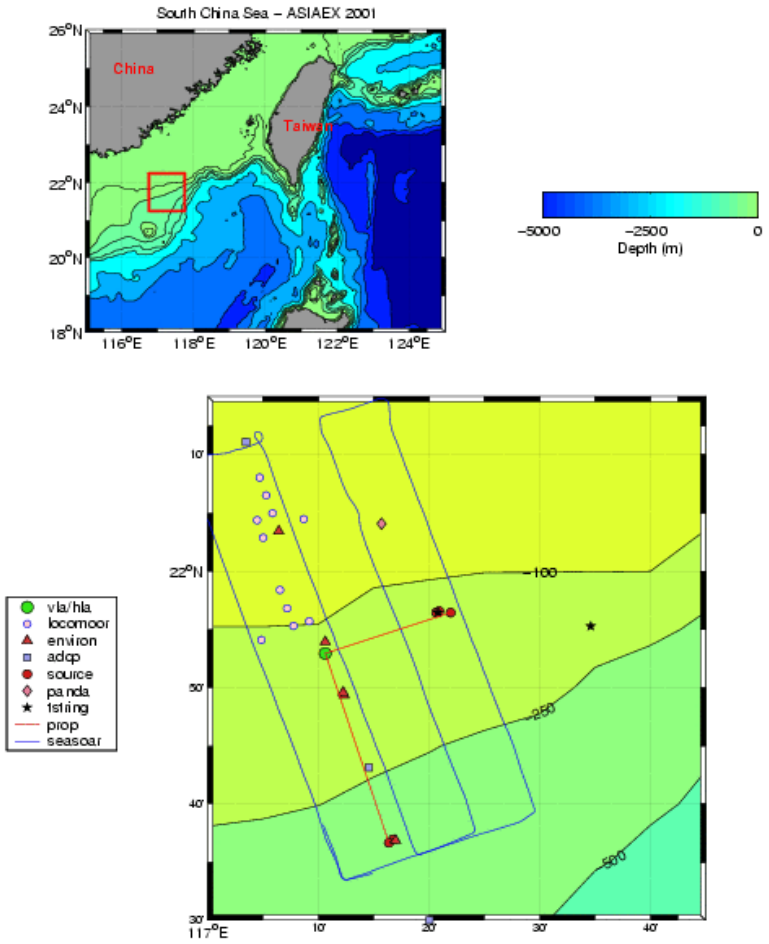

Figure 1. Upper panel shows geographical location of ASIAEX SCS volume interaction experiment. Lower panel shows locations of moorings, as well as fixed acoustic paths and Sea Soar tracks.

paths, as well as the propagation loss tows. (We had hoped for somewhat more geological data, but area permission problems in the FY 2000 preliminary experiment precluded our obtaining all the data we desired. We are hoping that a further chirp sonar survey by L. Bartek, planned for spring, 1993, can remedy this.) Our experiment extended temporally over a three-week period, so that we were able to examine the effects of a full spring-neap tidal cycle on the acoustics transmissions.

WORK COMPLETED

Our main accomplishment this year was the initiation of full scale data analysis efforts, concentrating on (as mentioned above) horizontal array coherence, travel time and amplitude fluctuations, and the ambient noise field. This work was performed in close collaboration with other ASIAEX PI's, specifically: M. Orr (and his group) from the Naval Research Laboratory (horizontal array coherence), Lixin Wu of the National Laboratory of Acoustics in Beijing and T. Duda of WHOI (amplitude and travel time fluctuations), and R.C. Wei of the National Sun Yat Sen University in Kaohsiung (ambient

noise). Each of these studies has progressed well, and we are planning to publish a paper on each topic in the upcoming IEEE Journal of Oceanic Engineering special issue devoted to the Asian Marginal Seas. The current results in each area will also be presented at an ASIAEX workshop in Chengdu, China this coming October. It should be noted that Drs. Wu and Wei both came to WHOI as Guest Investigators during the summer of 2002, enabling us to work closely. Several visits to NRL also help facilitate the interaction on the analysis work. Additionally, we (Newhall and Lynch) were able to visit both the Beijing and Kaohsiung laboratories of our Guest Investigators this past year as guests of their institutions.

RESULTS

We are at the "intermediate" stage in all the analyses, which means that we now have some interesting results to report, though not the complete story.

In the horizontal array coherence analysis, we have performed the critical array element location studies using three different methods: 1) long-baseline high frequency navigation, 2) dropped light-bulb sources, and 3) distant source low frequency navigation. All these methods showed basic agreement, with the distant, low-frequency source localization showing probably the best accuracy. Having these localizations in hand, we have embarked on obtaining the horizontal coherence length via two methods: 1) phone-to-phone cross correlation of the pulses and 2) studies of the beamformed array gain. The correlation calculations gave an ~20λ value for the array horizontal coherence, which is probably a lower bound, as the mode temporal dispersion due to the non-perpendicular array geometry probably decreased this horizontal coherence estimate. The beamformed outputs have been obtained for most of the acoustic frequencies used, but we are just at the stage of converting these into coherence length estimates.

Turning to the travel time and intensity fluctuation analyses, we again are at the halfway stage, where we have time series of many quantities of interest, but have not studied all the inter-correlations of the acoustics and environmental variables. In Figure 2, we show an example of the leading edge travel time (black dots – green is a higher threshold), pulse intensity centroid (blue), and full pulse width (red) over an approximately one day period, showing clear evidence of the diurnal tidal modulation of these signals. We currently have full time series for these travel time related variables, as well as most of the intensity variables. Time series for the prime oceanographic correlates to the acoustics (temperature and current) also exist, and so we should soon be able to comment in some detail about the forcing of the acoustics by the environment. Finally, we note that we also have noise time series at 700 Hz and above, and at 350-450 Hz, with more bands to be analyzed shortly. Again, these time series can be quickly correlated to environmental forcing.

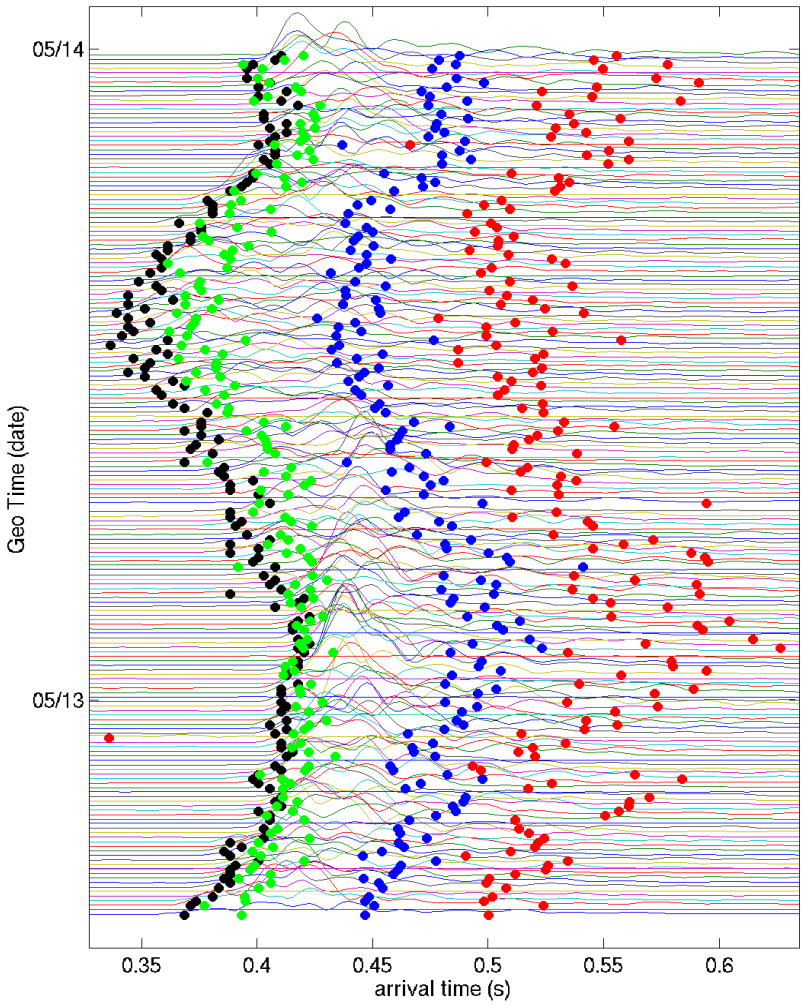

Figure 2. Tracking of the leading edge travel time (black and green dots, using slightly different thresholds), pulse centroid (blue dots), and full pulse time spread (red dots) for one day of data from the ASAIEX experiment. (Courtesy T. Duda.)

IMPACT

Probably the greatest impact that the ASIAEX volume interaction experiment will have is in seeing just how well we can predict the acoustic field and its variability/fluctuation level for a case where we can check the answers against ground truth. Additionally, we can directly examine important quantities such as horizontal coherence length and the frequency dependence of acoustic propagation for the ASIAEX region. Finally, the oceanographic data taken will be of great use in calibrating Navy models, such as MODAS.

TRANSITIONS

One eventual transition of our data will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction. Also, our ASIAEX data provide a unique database in a region where there are relatively few high-quality data.

RELATED PROJECTS

The SWARM acoustics/internal wave study and the PRIMER acoustics/shelfbreak front study were direct predecessors of ASIAEX, and examined some of the same scientific issues, only with fewer measurement resources. The Uncertainty DRI is also a closely related project to ASIAEX, as it will use some of the data.

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